



# Validation of a Neuroimaging Task to Investigate Decisions Involving Visceral Immediate Rewards



Xiaobei Zhang<sup>1</sup>, Shan Luo<sup>2</sup>, Kathleen Page<sup>2,4</sup>, John Monterosso<sup>1,3,4</sup>

<sup>1</sup>Department of Psychology, University of Southern California, <sup>2</sup>Keck Department of Medicine, University of Southern California <sup>3</sup>Brain and Creativity Institute, University of Southern California, <sup>4</sup>Graduate Program in Neuroscience, University of Southern California

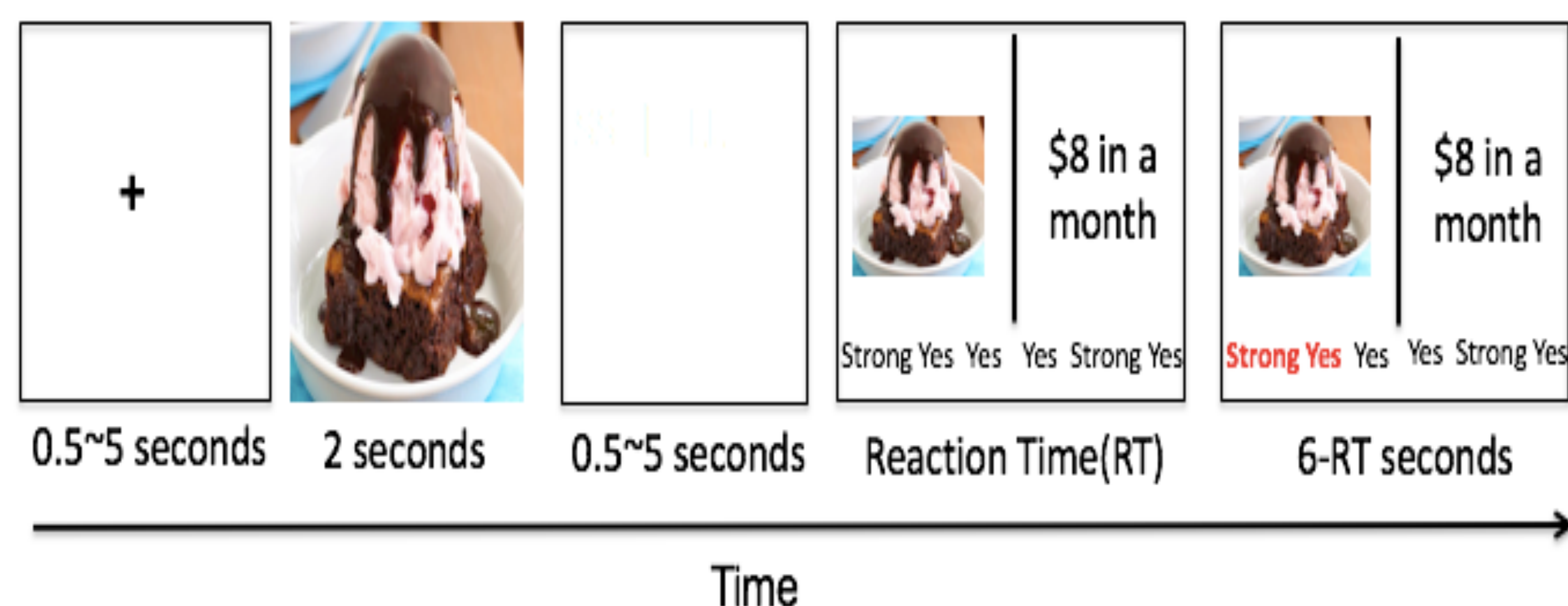
## Introduction

- Neuroeconomic investigation of now-later trade-offs have relied on intertemporal monetary choice tasks. While monetary rewards allow precise modeling, they do not generate the strong visceral states associated with immediately available primary rewards such as eating. The study verified the feasibility of the hybrid task including both visceral content (visual depiction of immediately available food) and elements of a conventional delay discounting task (monetary bonuses), so that the effect of visceral factors on decisions can be better studied in the MRI environment.
- To verify the the feasibility of the new paradigm, several hypotheses are made based on conventional monetary delay discounting task.
- **Hypothesis 1:** Food choices are selected more when the delayed money alternative is smaller.
- **Hypothesis 2:** The reaction time will increase when the delayed reward is close to the willingness to pay (“indifference point” for the food item).
- **Hypothesis 3:** The willingness to pay is higher when there is greater metabolic deficit.
- **A preliminary brain data analysis** was conducted to see the brain correlates of the food priming cues and how brain signal can predict the choice.

## Methods

- Twenty-four volunteers (14 female; 10 male; mean age  $21.6 \pm 2$ , range 16–25 y; mean BMI  $29.0 \pm 7.4$ , range 19.6–45.4 kg/m<sup>2</sup>) with no history of eating disorders, diabetes, or other medical illnesses participated in the study. For some participants (n = 16), an additional water session was included.
- **Decision-Making Task.** Repeated choices were made between immediately available food items and different monetary bonuses available in one month (Food vs. Future Money Task – FFMT). Participants completed the FFMT in multiple sessions in different metabolic states (glucose, water).
- The food item presentation was pseudorandom, with each session including six presentations of each of the 10 attractive food items for the individual.
- Choices titrated to maximize decision difficulty.

### Trial Start



- A preliminary analysis was carried out using brain activity during the presentation of the food item alone at the beginning of each trial.
- Aimed at answering the question “Can brain activity during the presentation of the food item predict how often it will be selected by a participant?”

## Data Analysis and Results

- **Hypothesis 1:**
- A simple logistic regression (base model) was performed with choice (Food or Money) as the dependent variable, delayed money alternative as the predictor. Alternatively, data was analyzed with logistic hierarchical regression models using the R lmer function of the lme4 library to take into account trial-by-trial variance in individuals’ choices.
- Data were fitted using logit and probit model separately. Results from these two models were compared based on Akaike Information Criterion (AIC). AIC has been widely used in model comparison and selection (Anderson & Burnham, 2002). The smaller the AIC, the better the model.
- We found that for all the models and methods we used, Food choices were significantly selected more when the delayed money alternative was smaller ( $p < 0.05$ ).
- After model comparison (see table1), the fourth model using “logit” method has the smallest AIC is the best fitting model.

	AIC		ΔAIC
logistic regression	Logit	Probit	
First: Base Model	6644.1	6643.9	0.2
Second: Random slope and intercept, look it by ID	5527.1	5526.1	1
Third: Random slope and intercept, look it by ID and Food	5514.2	5512.7	1.5
Fourth: Random slope and intercept, each food is nested within each subject	5322.7	5327.8	-5.1

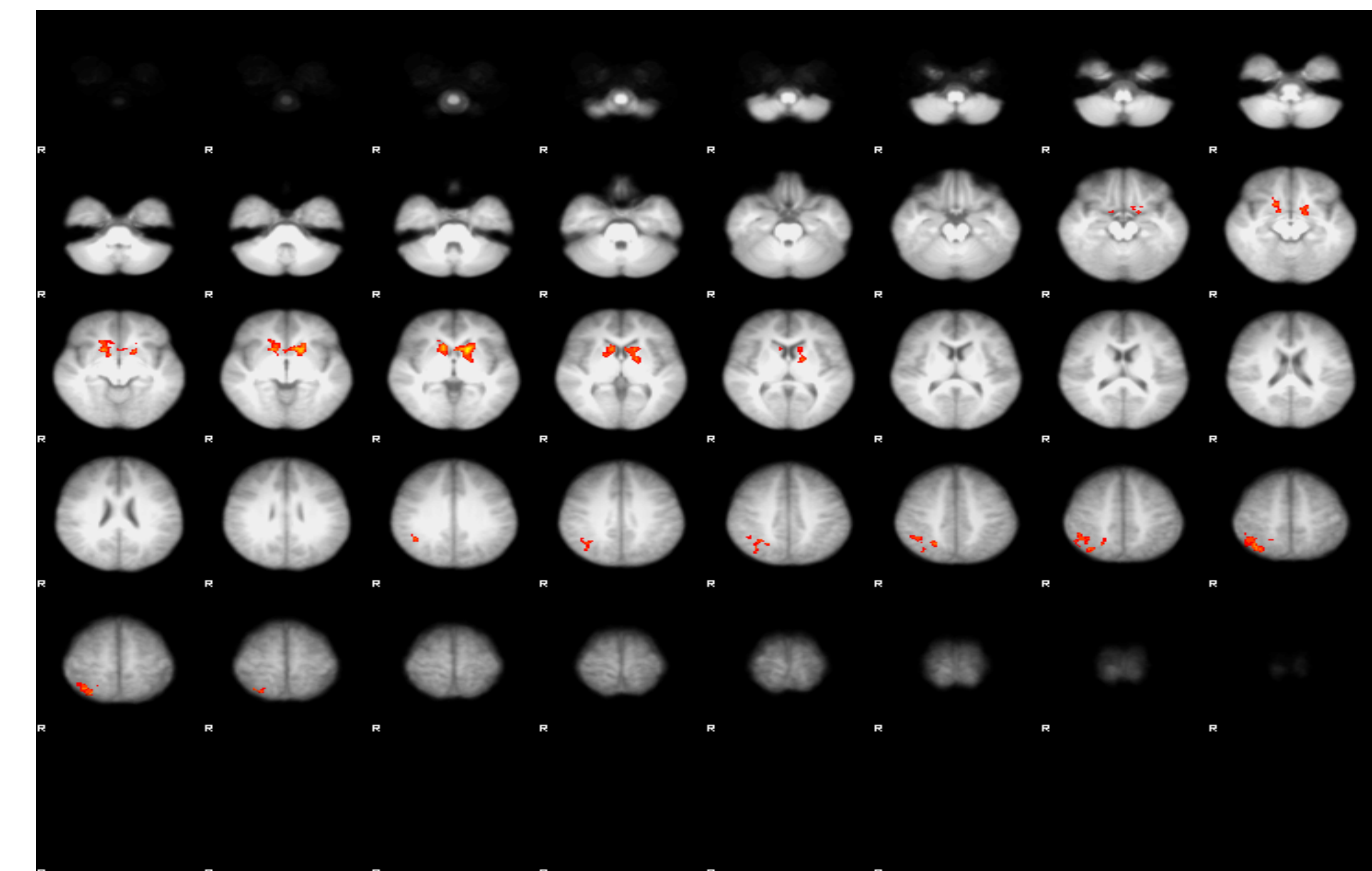
- **Hypothesis 2:**
- Using a subset of participants who had at least one WTP estimate, we conducted linear regression and hierarchical regression. A base model included Reaction time as dependent variable, the difference between the delayed reward (will call this as “distance”) and the willingness to pay ( $(|WTP - Delayed\ reward|) / (WTP + Delayed\ reward)$ ) as the predictor.
- We found that for all the models we used, the reaction time increased significantly when the delayed reward was close to the willingness to pay ( $p < 0.05$ ).
- Based on the AIC criterion for model comparison (see table 2), the best fit was observed for the fourth model.

Linear regression	AIC
First: Base Model	9807.2
Second: Random slope and intercept, look it by ID	8941
Third: Random slope and intercept, look it by ID and Food	8945.9
Fourth: Random slope and intercept, each food is nested within each subject	8925.7

- **Hypothesis 3:**
- Using a subset of participants who additionally completed a water session, we observed that, relative to water, glucose resulted in significantly decreased WTP-delayed ( $Z = -2.245$ ,  $P = 0.025$  for glucose vs. water). The willingness to pay is higher when there is greater metabolic deficit.

## Data Analysis and Results

- **Order effect analysis:**
- For Hypothesis 1, We found delayed money alternative ( $p = 0.005$  with probit model,  $p = 0.006$  with logit model) can significantly predict the later choice after controlling for sequence.
- For Hypothesis 2, after adding the new predictor trial sequence number, the “distance” is still a significant predictor ( $p < 0.001$ ) for RT.



- **Brain data analysis:**
- These contrast maps were based on whole-brain analysis during the food-cue period in every voxel ( $Z > 2.3$ ,  $p < 0.05$  corrected for multiple comparisons).
- Greater activation in ventral striatum, caudate, lateral occipital cortex were all associated with preference to select immediate food over delayed money.

## Discussion

- In summary, we successfully verified the feasibility of the new paradigm incorporating visceral-factor alternative into the conventional monetary delay discounting task. It’s worth mentioning that the delay in the new paradigm was used to model real-life situations in which the benefits of turning down foods come later in time. This task can be used to separate the brain correlates of “Food approach” and eating “Restraint.”
- The best fitting models for both hypotheses take care of the individual differences and the data structure. Future study using the same model with different visceral-factor alternatives should also consider the individual differences and the data structure.
- Some participants showed a significant slowing when the delayed reward was near the willingness to pay, possibly related to decision difficulty and/or ambivalence. Ongoing neuroimaging analysis will compare subjects with and without this pattern.
- Greater food-cue reactivity in the ventral striatum was positively related to the frequency of food choices, this suggests greater reward and motivation signaling for food cues can predict the later preference for the food choice.